AD NUMBER

AD092935

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 31 MAR 1956. Other requests shall be referred to Office of Naval Research, Arlington, VA 22203.

AUTHORITY

ONR ltr dtd 28 Jul 1977

FC

4/9

ELECTRICAL ENGINEERING RESEARCH LABORATORY
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

STATUS REPORT
ON
DIRECTION OF ARRIVAL OF
RADIO WAVES

Project No. NR-371-161
Contract No. Nonr 1834(02)
Report No. DF 1

31 March 1956

Period Covered:

1 December 1955

to

29 February 1956

Approved by:

A. D. Bailey
Associate Professor

H. D. Webb
Associate Professor

Supported by Office of Naval Research

Radio Direction Finding Section
Electrical Engineering Research Laboratory
Engineering Experiment Station
University of Illinois
Urbana, Illinois

DISTRIBUTION LIST FOR STATUS REPORTS

Contract Nonr 1834(02)
ONR Project No. 371-161

Addressee	Attn:	No. of Copies
Chief of Naval Research Department of the Navy Washington 25, D. C.	Code 427	2
Director Office of Naval Research Branch Office Tenth Floor The John Crerar Library Building 86 East Randolph Street Chicago 1, Illinois		2
Director Office of Naval Research Branch Office 346 Broadway New York 13, New York		1
Director Office of Naval Research Branch Office 1030 E. Green Street Pasadena 1, California		1
Officer-in-Charge Office of Naval Research Navy #100 Fleet Post Office New York, New York		2
Chief of Naval Operations Department of the Navy Washington 25, D. C.	Code Op 20X Op 371C	1 1
Commanding General Office of the Chief Signal Officer Engineering and Technical Division Department of the Army Washington 25, D. C.		1
Commander Operational Development Force U. S. Naval Base Norfolk 11, Virginia		1
Central Intelligence Agency 2430 E. Street, N. W. Washington 25, D. C.	Harrie A. James Chief, Liaison Div. Collection & Dissemination	1

DISTRIBUTION LIST (Cont.)

Addressee	*Attn:*	*No. of Copies*
Chief, Bureau of Ships Navy Department Washington, D. C.	Code 327	6

1. GENERAL INFORMATION

1.1 Initiation of Contract Nonr 1834(02)

The Contract Nonr 1834(02) has replaced Contract N6-ori-07115 under ONR Project Number NR 371-161. The effective starting date of the new contract was 1 October 1955.

The last status report under N6-ori-07115, numbered DF 36, covered the period 1 September 1955 to 30 November 1955. It is explained in that report that one month of the period was under the new contract. This was before the starting date of the new contract was known. Actually Report No. DF 36 covered *two* months under Nonr 1834(02).

1.2 Personnel

The names of the men working under this contract as of this date, and the percent of their time charged to the contract, are as follows:

A. D. Bailey, Associate Professor	50%
H. D. Webb, Associate Professor	50%
E. C. Hayden, Research Associate	50%
D. L. Bitzer, Research Assistant	50%
S. E. Leifheit, Research Assistant	75%
R. L. Sydnor, Research Assistant	75%
A. J. Wavering, Research Assistant	50%

1.3 Report Policy

Since this contract is under the ONR project number NR 371-161, the same number used for contract N6-ori-07115, the procedure for reports will be the same as that followed under the earlier contract until other information is received. This procedure calls for brief quarterly status reports and detailed technical reports to be issued as projects are completed or as it seems desirable.

1.4 Nature of the Work

There are some projects and some phases of projects which were nearly completed under N6-ori-07115. It is expected that technical reports on this work will be issued under this new contract within a few months.

The work that is reported in Section 2 is, for the most part, work that was started under N6-ori-07115 and is being continued under this contract.

1.5 Visitors

Four persons visited the RDF section during this quarter to discuss RDF problems. They were: Mr. R. Silberstein of the National Bureau of Standards, Boulder, Colorado, and Mr. Lloyd White, Capt. H. E. Armstrong, and Cdr. O. S. Knudsen of Office of Naval Research, Chicago.

1.6 Reports Issued

Two reports were issued during this quarter under Contract N6-ori-07115:

1. Technical Report No. 23, *A Phase and Gain Matched Three-Channel Intermediate-Frequency Amplifier*, by T. R. O'Meara, and
2. *Final Report on Direction of Arrival of Radio Waves.*

2. SUMMARY OF RESEARCH

The work under the contract is divided into several projects. Summaries of research accomplished and statements of the present status of the projects follow.

2.1 Direction of Arrival of Waves - E. C. Hayden, S. E. Leifheit, and R. S. Smith

2.1.1 Antenna Error Study

During this quarter error data from measurements made on an Adcock antenna system have been subjected to a numerical analysis. The purpose was to study methods of evaluating an RDF installation. Some statistical techniques have been applied to put a numerical value on the "badness" of the installation. Fourier analysis techniques have been applied to try to show causes of error. Contour maps of error on a frequency-azimuth plane have been drawn to show the behavior of error as a function of frequency.

The numerical techniques have been tedious to carry out manually. Consequently, programs have been prepared for doing some of these jobs on the Illiac - the University's digital computer. Programs have been prepared for a 72-ordinate Fourier analysis giving 18 harmonics, and for computation of spacing error. Programs are available in the Illiac library for the standard statistical operations (finding means, rms values, etc.).

With the advent of warmer weather it is intended that more data be obtained for analysis by these means.

2.1.2 Ground Constant Study

A survey of the literature on measurement of ground constants has been completed, and a summary report on the findings is partially completed.

2.1.3 Receiver Modifications

Experience with the multi-channel RDF receiver built for use at the field station has dictated the need for certain modifications. These have been made. The need for changes arose primarily from two sources.

The first source of difficulty lay in the insufficient amount of adjustment provided in certain circuitry. The range of adjustment was purposely made small in order to improve stability. Adjustable components are generally less stable than fixed components, especially since the latter can be potted. However, the adjustment range must be large enough to counter long-time (months or years) drift in the values of the components. This was not the case in some instances. In addition, trouble has been experienced from the use of signal generators with a calibration tolerance greater than the range of adjustment provided in the receiver. Thus, if the receiver were initially adjusted with one generator, it might be impossible to satisfactorily adjust it with another. Part of the solution to this problem is, of course, to use more accurate generators. This has been done by using crystal-controlled oscillators to generate strategically chosen frequencies for alignment.

The second source of difficulty lay in the third converter and low-frequency output circuits incorporated in the receiver. The low-frequency output is needed for operation of bearing averaging equipment, reported under Section 2.3. However, it does not give a satisfactory display of the pulse signals being used in the signal structure studies. In addition, a certain amount of noise and distortion originate in this converter. The receiver has been modified to provide both a low frequency (10 kc) output for the bearing averaging equipment, and a high frequency (455 kc) output for the signal structure display equipment.

2.1.4 Field Station Site

A situation concerning the field station site has arisen which requires some immediate attention. For the past several years the RDF group has operated a field station on the University airport. The facilities are badly in need of rehabilitation and expansion. However, it appears that such rehabilitation and expansion will conflict with plans which the University Institute of Aviation has for the area. Indeed, it appears likely that the present installation will have to be removed within two years. If the work is to continue without interruption, a new site shouldbe found immediately, since it will take some time to prepare it for use. Another aspect needing consideration is that it was intended to use these facilities in connection with BuShips Contract Nobsr 64723.

2.2 Matched Channel Amplifier Problem - H. D. Webb and D. L. Bitzer

2.2.1 Wide Band Receiver with Signal Selection by Local Oscillator Tuning Only

In 1950 work was started on a receiver with fixed-tuned RF amplifiers, with signal selection to be made by varying the local oscillator. Image rejection was to be obtained by using a staggered-tuned RF amplifier and by careful choice of first IF in a double frequency conversion system. The work has been interrupted many times due to work on related projects. During the course of the work many problems connected with matched-channel receivers were encountered. Good solutions were obtained for some of these problems, and they are discussed in several technical reports.

Also, many changes and modifications were made - so many, in fact, that the receiver became a testing laboratory on its own merit. Consequently, it was never completed as a receiver for field testing. Laboratory tests have indicated that the receiver is feasible in principle. For this reason a technical report is in preparation in which the main problems, principles, and circuitry are discussed.

A model suitable for field testing and for use as a panoramic RDF receiver is being planned.

2.2.2 Panoramic Receiver

During this quarter most of the work under this heading has been directed toward methods of displaying the frequency and bearing information made available at the output of a panoramic RDF receiver.

The display system mentioned in Report No. DF 36 under Contract N6-ori-07115 would have the bearing displayed as a CRT trace in the usual manner for a Watson-Watt system. The frequency information was to be displayed as a brightened spot along the trace, with the distance of the brightened spot from the center of the CRT an indication of frequency. Two difficulties were encountered: (1) the circuitry worked out required a nearly constant amplitude receiver output, and (2) an elliptical bearing trace would greatly decrease the indicated frequency accuracy.

Presently a Cartesian-coordinate, or A-B, type display which shows promise is being studied. The bearing is to be displayed along the horizontal axis and the frequency along the vertical axis.

One objection to a panoramic display is that a large amount of information is made available, but only a small amount of this information is useful. An operator, therefore, has the chore of sorting out the useful information. The work of the operator could be lessened if some sort of censoring could be built into the receiving system. The Cartesian type of display would place a small dot on the face of the CRT. Censoring could be accomplished by placing a mask over the face of the CRT and by painting out indications due to undesired signals, such as, for example, bearing and frequency indications for signals that are known to be always present.

With the Cartesian display, the bearing information is derived from the major axis of the ellipse that appears in the Watson-Watt display. This is accomplished by means of two pulses. To derive the pulses, the signal from one channel, say, the NS channel, is shifted 90° at IF and added to the EW signal, also at IF. A pulse is generated from the leading edge of the squared sine wave from the carrier. The NS signal is then shifted -90° at IF and added to the EW signal. A second pulse is generated from the leading edge of the squared sine wave for this signal. The time difference between these two pulses is equal to twice the bearing angle. The frequency display is derived from the swept frequency oscillator.

The bearing display portion is being studied without sweeping the frequency in order to determine the accuracy and reliability. If this is found satisfactory, the complete display system will be tested with various frequency sweeping rates.

2.2.3 Injection-Type Matched Channel Receiver

The Canadian CRDF, which was obtained on indefinite loan, is being modified to operate as an injection-type, matched-channel RDF receiver. A block diagram of such a receiving system is shown in Technical Report No. 21, Contract N6-ori-07115.

With this system the injection signal is derived from the receiver local oscillator and a fixed oscillator at a frequency removed one kilocycle from the receiver IF. The injection signal then differs from the incoming signal by one kilocycle. The magnitude of the injection signal must be controllable so that it will always be 30 to 40 decibels above the incoming signal. The last IF is at one kilocycle following a square-law detector. According to a theory developed in Technical Report No. 21,

this system should give a substantial decrease in phase error due to mismatch in the receiver, possibly by as much as 50 times. It is also necessary to correct the gains of the two channels by means of an AGC system derived from the injected signal.

To date, the work has been directed toward the generation of the injection signal. Some circuits have been worked out, but they have not been tested for performance.

2.3 Application of Probability Theory and Statistical Inference to the Radio Direction Finding Problem - A. D. Bailey, R. L. Sydnor, and A. J. Wavering

2.3.1 Separate Channel Averaging

An IF sampling technique for a twin-channel cathode ray direction finder has been developed which preserves the sign and amplitude of each of the separate channel outputs over certain selected periods of time. A theoretical analysis of this mode of sampling has shown that, for a single incoming ray, there is no error in the indicated bearing. However, for cases of multiple ray signals, phase shifts occur which introduce error. The two-ray interference case has been analyzed and error curves have been evaluated for a representative case. Comparison of these error curves with those obtained for the conventional Watson-Watt display shows that the separate channel averaging technique yields the same order of average error! Two AIL Model 40 integrating amplifiers have been ordered and, upon their arrival, the proposed system will be evaluated in the laboratory on the direction finder analyzer and then later in the field. A bearing shifter is not required here.

2.3.2 Mark III Analog Bearing Computer

Field tests of this equipment have been held up due to receiver modifications. It is planned to continue the tests in the next quarter.

2.3.3 Spinning-Goniometer Bearing Computer

The results produced by averaging bearings from a dual-channel direction finder as demonstrated on Contract N6-ori-07115 have suggested that similar techniques could be applied to the single channel spinning-goniometer system, particularly the AN/GRD-6 direction finder. As far as computer applications are concerned, this direction finder is nearly identical to the DAK type direction finder, except

that it has available an accurately determined pulse at the instant of north search. The goniometers are rotated, as in the DAK, at 1200 rpm (20 rps). The problem is to obtain an electronic or mechanical device which will produce an output suitable for averaging or adding for a predetermined time. By far the simplest type of adding device is the R-C integrator, as typified by the Mark II integrator used by this project in the past or by the Model 40 integrator produced by Airborne Instruments Laboratories.

With such adding or integrating devices, the output of the spinning-goniometer computer must have waveforms (probably pulses) with an area proportional to the angle of arrival of the signal.

If one presupposes that the signals received by the DF are CW, then the solution of the problem is relatively straightforward. However, if the signals are of the pulsed, i.e., of the on-off variety, particularly if the minimum pulse length is less than the scan time of the goniometer, the problem is much more involved. This is true in the present case; the scan time of the goniometer is 50,000 μsec while the minimum pulse length of the signal for ordinary teletype transmission is approximately 5000 μsec. While an extremely crude sort of reading can be obtained by a human operator under these conditions, it is felt that the inherent accuracy of such a reading is so low under most conditions that the devising of any sort of computer to be used with the system is not practical, especially since the complexity and cost of such a computer would be rather great. One alternative remains, if one insists on using this type of direction finder in situations such as the above. One can decrease the scan time of the goniometer, preferably to a point such that it is less than one-half of the minimum signal pulse length expected. If this is done, the problem reduces to that of CW signals and is, therefore, relatively simple. Any other scheme devised calls for extensive modification of the goniometer and receiver, either by adding large numbers of goniometers, or by the simultaneous use of several (say, six to eight) receivers - a costly and complicated procedure in either case.

The chief difficulty is encountered in deciding what the computer for CW signals should be to cope with those cases when pulsed signals are received. If the device is incapable of differentiating between signal nulls and no-signal nulls, erroneous bearing would result from

pulsed signals. Because the philosophy of the design of this computer is to maintain simplicity, a censoring unit is required to eliminate all pulse bearings from consideration.

The original scheme for a computer as outlined above produced output pulses with an *amplitude* that was proportional to the direction of arrival of the incoming signal. This scheme was temporarily abandoned, since difficulty was encountered when the direction of arrival was in the neighborhood of 0°, or 180°.

A new system which appears more promising is now being built. This system produces a pulse, the *length* of which is proportional to the angle of arrival of the incoming signal.

If computers are desired for short pulse direction finding, it appears that the slow speed spinning-goniometer type systems may have to give way in favor of dual-channel receivers. A typical dual-channel receiver has a scan time of 2 μsec, allowing accurate direction finding on pulses of extremely short width. They are also better suited for computer attachment, either analog or digital.